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SCOUT VEHICLE AERODYNAMIC-NOISE MEASUREMENTS

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ABSTRACT

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The results of recent free-flight surface-pressure measurements are presented for the NASA Scout launch vehicle for Mach numbers up to about 4, free-stream dynamic pressures up to about 2,300 pounds per square foot, and Reynolds numbers based on vehicle length up to about 400 million. Useful data from two onboard microphones up to the time of second-stage firing were telemetered to the ground station for recording and analysis. The overall surface noise levels were noted to increase roughly as the dynamic pressure increased, but did not vary markedly as a function of Mach number. However, a Mach number effect on the spectral content of the surface noise pressures was noted as a general result of the tests. In particular, the spectra at the higher Mach numbers contained relatively more high-frequency noise and relatively less low-frequency noise than spectra measured at low speeds. The results of the above tests are compared with available data from other free-flight studies.

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INTRODUCTION

For a variety of flight vehicles, aerodynamic noise is significant from the standpoint of exciting directly the vibration modes of the surface structure, causing sensitive equipment to malfunction, and interfering with the normal duty functions of the vehicle occupants. Interest has been intensified in recent years in this problem because aerodynamically induced disturbances are inherently more important with regard to high-performance aircraft and launch vehicles. Although a large number of aerodynamic-noise studies have been made, most of these have been analytical in nature or have involved laboratory experiments rather than free-flight-type experiments (see ref. 1). It is particularly desirable to have full-scale free-flight data which apply directly to realistic ranges of flight conditions and for comparison with other studies.

The free-flight conditions for which aerodynamic-noise data are available (see refs. 2 to 8) can be summarized briefly with the aid of figure 1. In figure 1 are plotted the ranges of Reynolds numbers associated with the operation of three types of test vehicles as a function of Mach number. As represented by the crosshatched area, it can be seen that data are available for fighter-type aircraft for Mach numbers up to 2 but for only a limited range of Reynolds numbers. As indicated by the hatched region, for bombers and transport-type aircraft the Reynolds number range is more extensive but the Mach number range is limited. Although several attempts have been made to obtain launch-vehicle measurements for the ranges indicated by the shading on the figure, no comparable systematic data are available. Research results to date (see refs. 3 and 7) have suggested that both Mach number and Reynolds number are significant parameters. With regard both to launch vehicles and the proposed supersonic transport, there is a need for measurements in the range of Mach numbers and Reynolds numbers encompassed by the solid curve. Because of the operational limitations of current aircraft, it is necessary to make use of launch vehicles in order to obtain data in this latter Mach number - Reynolds number range. The present paper describes the use of the Scout launch vehicle for this purpose and presents a summary of flight-test results (see ref. 9).

SCOUT VEHICLE PERFORMANCE AND DESCRIPTION

An indication of the range of Reynolds numbers and Mach numbers associated with the Scout launch-vehicle trajectory is given in figure 2. The Reynolds numbers were calculated based on distance rearward from the nose of the vehicle to

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the transducer location. The range of Reynolds numbers indicated was associated with two instrument locations on the vehicle. As a matter of interest it can be seen that the Reynolds number range extends above 200 million for a range of Mach numbers of particular interest for the supersonic transport and for various launch vehicles.

The test-vehicle shape and significant dimensions, along with the onboard equipment, can be described with the aid of figure 3. The vehicle was roughly 72 feet in length with a maximum diameter of 40 inches. The two microphone measuring stations were located approximately 34 feet and 68 feet, respectively, back from the nose. The nature of the onboard measuring and telemetering equipment is indicated by the photographs at the left-hand side of the vehicle. All of this onboard equipment with the exception of the battery-power supply and cabling weighed about 4 pounds, and the largest dimension was approximately 7 inches. The microphones had a diameter of about 1/2 inch, were flush mounted in the vehicle surface, and were connected to an FM telemeter transmitter through the associated amplifier and carrier equipment shown. These instruments, together with the ground-station tape-recording equipment, provided a frequency range of about 50 to 10,000 cps for each microphone channel.

The nature of the experiment plus a schematic indication of the manner in which data were acquired are shown in figure 4. The aerodynamic-noise equipment was carried as a "piggy-back" payload in conjunction with the launching of reentry payload. The vehicle was launched from Wallops Island, Virginia, and was tracked by means of a nearby radar facility. The telemeter system transmitted real-time noise data from both microphones using one data link. The signal was received and tape recorded at the ground station, also located at Wallops Island. Usable data were obtained up to the time of second-stage ignition. Thus, the data included first-stage burning, during which time the vehicle passed through the maximum dynamic-pressure condition and achieved a Mach number of about 4, plus the coast period between first-stage burnout and second-stage ignition. The maximum distance between the vehicle and the receiving station during the time of data acquisition was approximately 30 miles, at which time the vehicle was at approximately 100,000 feet altitude.

PRESENTATION OF MEASURED DATA

As in some previous experiments, it was noted that the noise pressures increased as the free-stream dynamic pressure increased. This phenomenon is illustrated by the curves of figure 5 in which the vehicle free-stream dynamic pressure and the measured noise pressures are both plotted as a function of Mach number. It can be seen that at the lower Mach numbers the noise-pressure curve follows the dynamic-pressure curve quite closely. It can, however, be seen that the noise-pressure curve peaks at a lower Mach number than the dynamic-pressure curve and, furthermore, there is a deviation from the dynamic-pressure curve at higher Mach numbers. This deviation may be explained in part by a Mach number effect which is shown in figure 6 and which will be explained in more detail during the discussion of figure 7.

This effect is illustrated by the data of figure 6 in which the surface-coefficient $\sqrt{\overline{p^2}}/q$ is plotted as a function of Mach number for the data obtained at the two measuring stations. The solid portions of the curve suggest a trend toward reduced surface pressure coefficients at the higher Mach numbers. The dashed portions of the curve at high Mach numbers correspond to flight conditions at high altitude and very low associated dynamic pressures. The signal-to-noise ratios are rather low at these latter conditions, and thus the dashed curves are based on less reliable data.

Analyses of the recorded data have indicated a definite effect of Mach number on the spectral content of the measured pressures, and this effect is illustrated in figure 7. Data are presented here for microphone 2 at two different times in the flight for which the dynamic pressure conditions were essentially equal but the Mach numbers were greatly different. The octave band spectrum for a Mach number of 0.67 is shown by the circle symbols, and the octave band spectrum obtained at Mach number 4.1 is represented by the square symbols. The spectra were noted to have a single broad peak, and this peak moved to higher frequencies as the Mach number increased. In the specific case illustrated in figure 7, this peak in the spectrum is noted to change from about 2,000 cps at the lower Mach number to about 8,000 cps at the higher Mach number.

There is a suggestion that the instruments did not have a sufficient frequency range to measure all the significant frequency components at the higher Mach numbers. Thus there is a tendency to underestimate the surface-pressure levels at the higher Mach numbers, and this would account, in part at least, for the effects noted at the higher Mach numbers in figures 5 and 6.

COMPARISON WITH OTHER DATA

The range of pressure-coefficient values measured for the Scout vehicle is compared with similar data from other free-flight studies in figure 8. It can be seen that these data compare favorably in magnitude with those measured for the B-47 and B-57 aircraft (see refs. 5 and 6) as indicated in the figure, and for which the Reynolds numbers were of comparable magnitude. These values are considerably higher than those measured on the nose cone of a fighter aircraft (ref. 4) for which the Reynolds numbers were much lower, and hence the local flow conditions might have been considerably different. The Scout data values are notably lower, however, than those measured for the Mercury spacecraft (ref. 8) which had rough external contouring and possible associated flow separation and shock-wave interactions.

CONCLUDING REMARKS

A brief discussion has been given of an experiment in which aerodynamic-noise data at high Reynolds numbers were obtained in the supersonic-speed range with the aid of a launch vehicle from which real-time information was telemetered to a ground recording station. The results of this experiment indicate a shift in spectrum shape as a function of Mach number, the higher frequencies being associated with the higher Mach numbers. Another result suggests that the surface-pressure coefficients at supersonic Mach numbers do not vary markedly from those at subsonic Mach numbers for comparable flow conditions.

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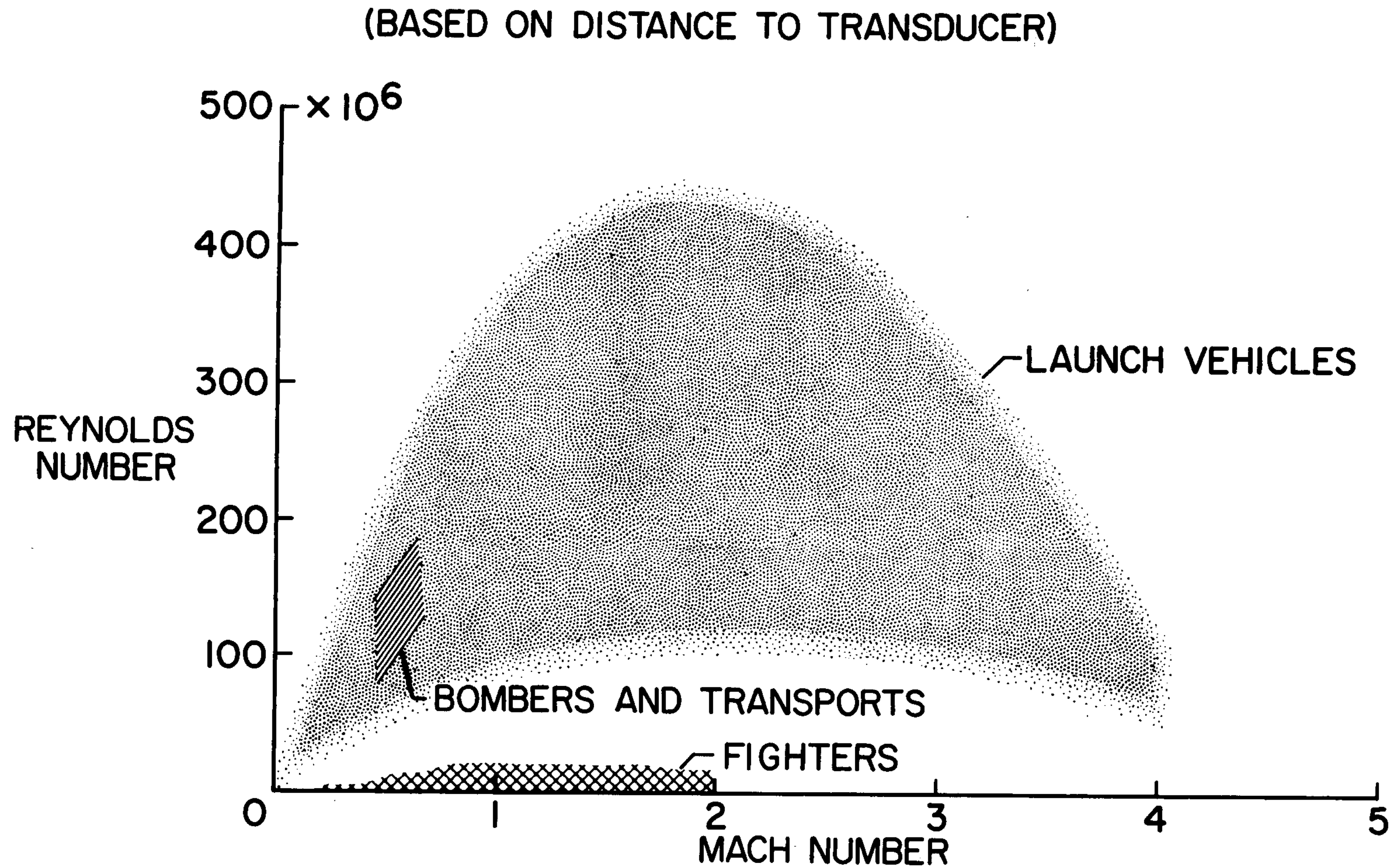

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Figure 1.- Flight data ranges of Reynolds number.

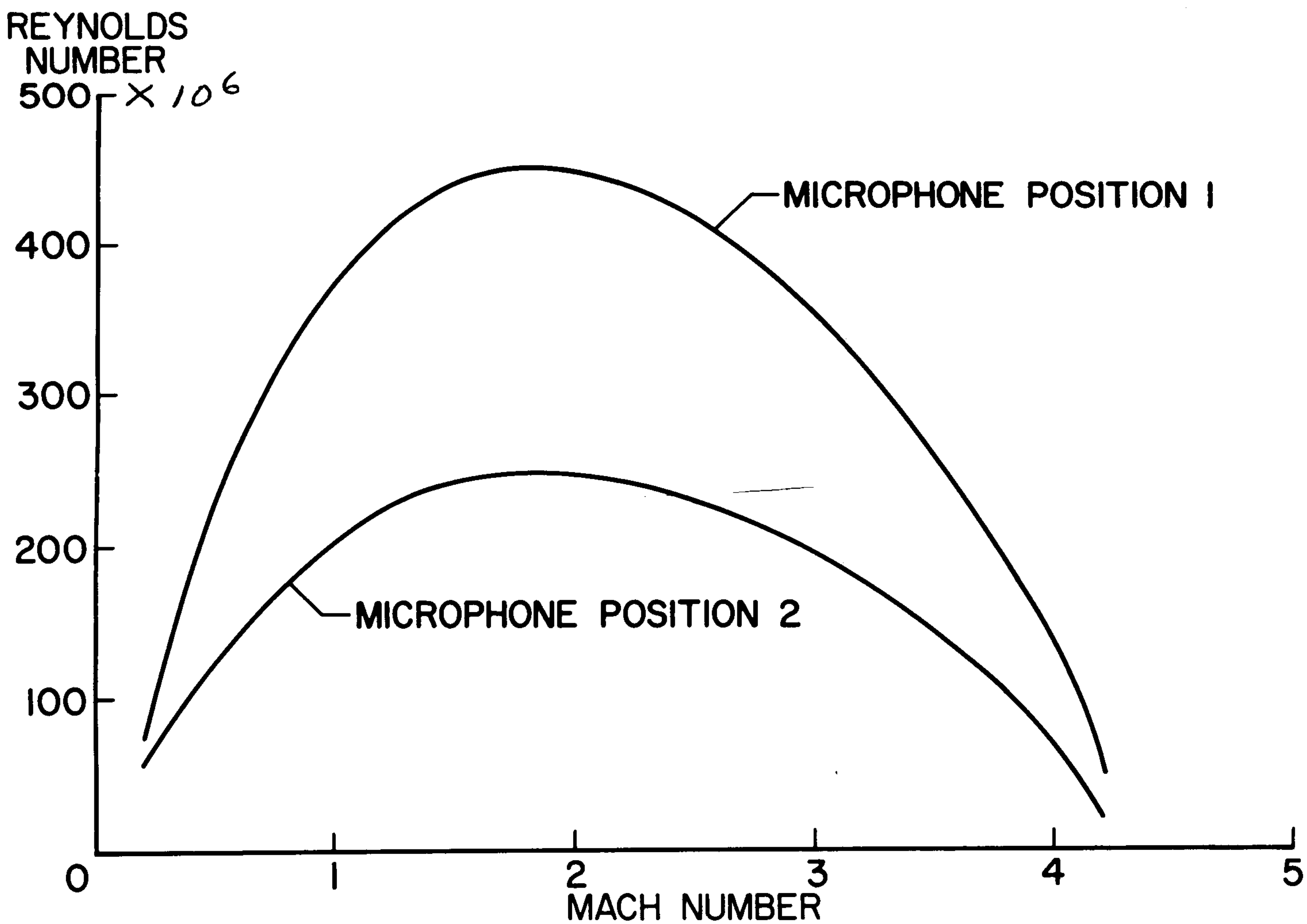

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Figure 2.- Scout vehicle operating conditions.

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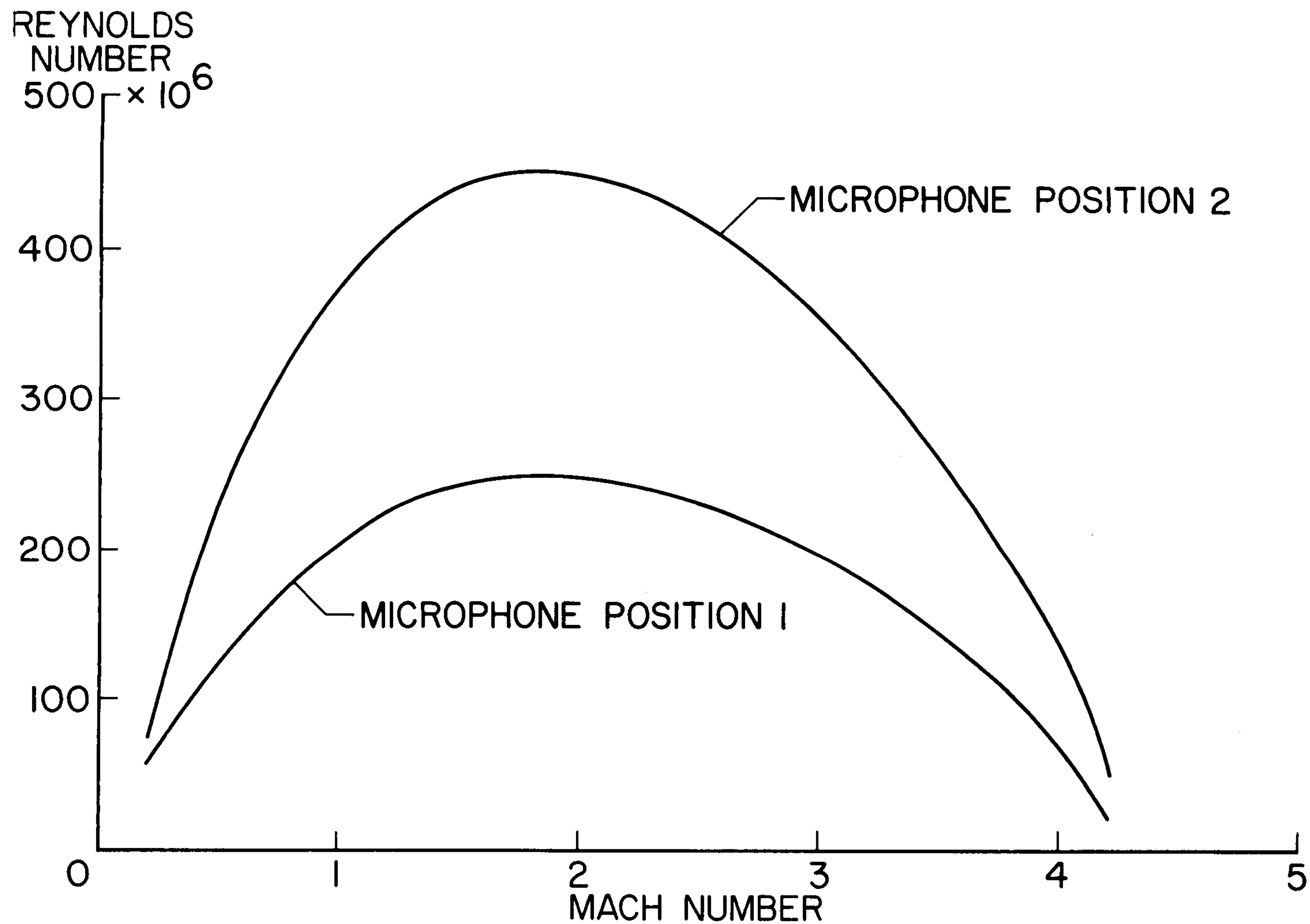

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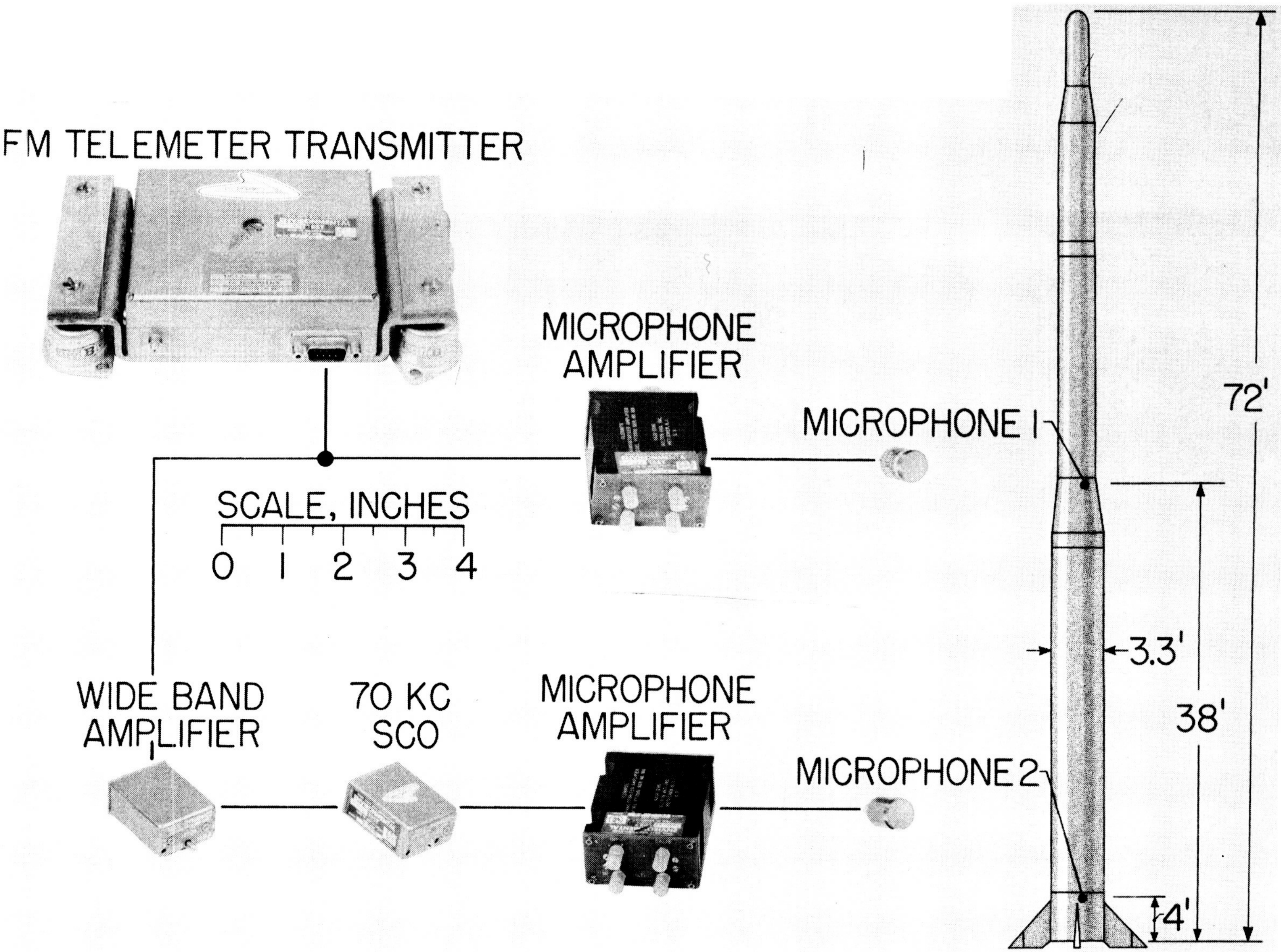

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Figure 3.- Instrumentation for Scout launch vehicle.

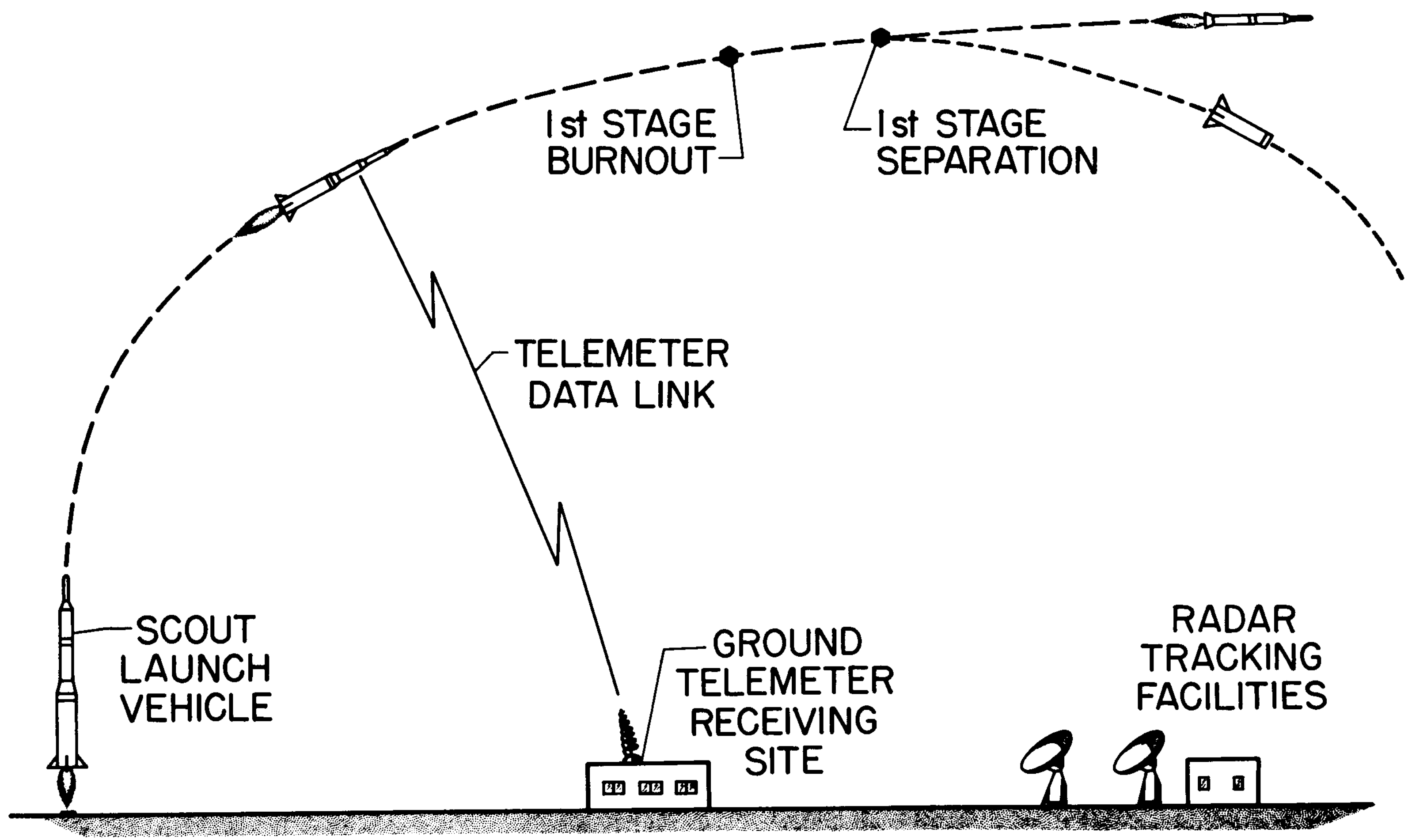

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Figure 4.- Acquisition of flight data for boundary-layer noise experiment.

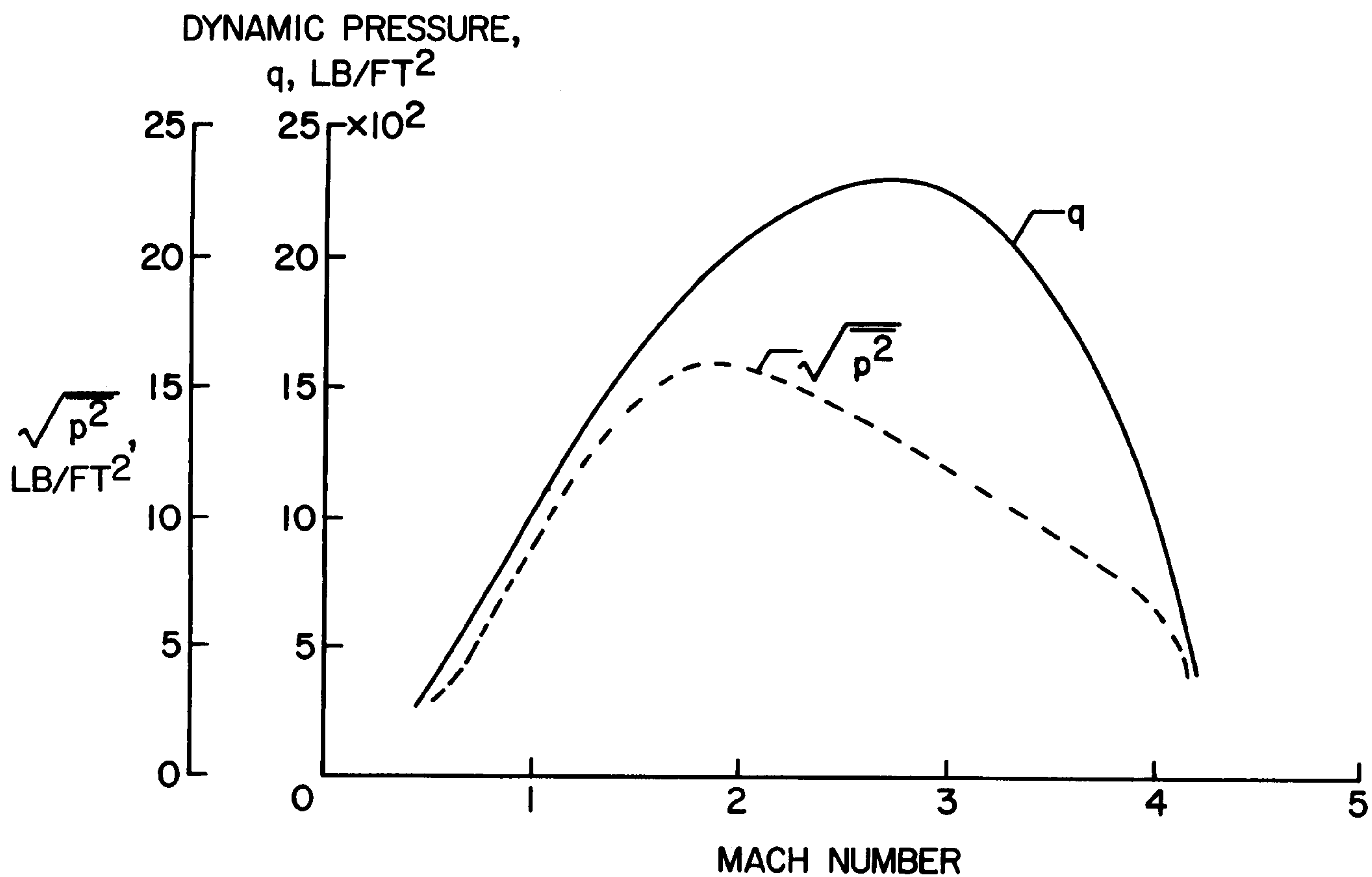

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Figure 5.- Correlation of noise pressure and free-stream dynamic pressure.

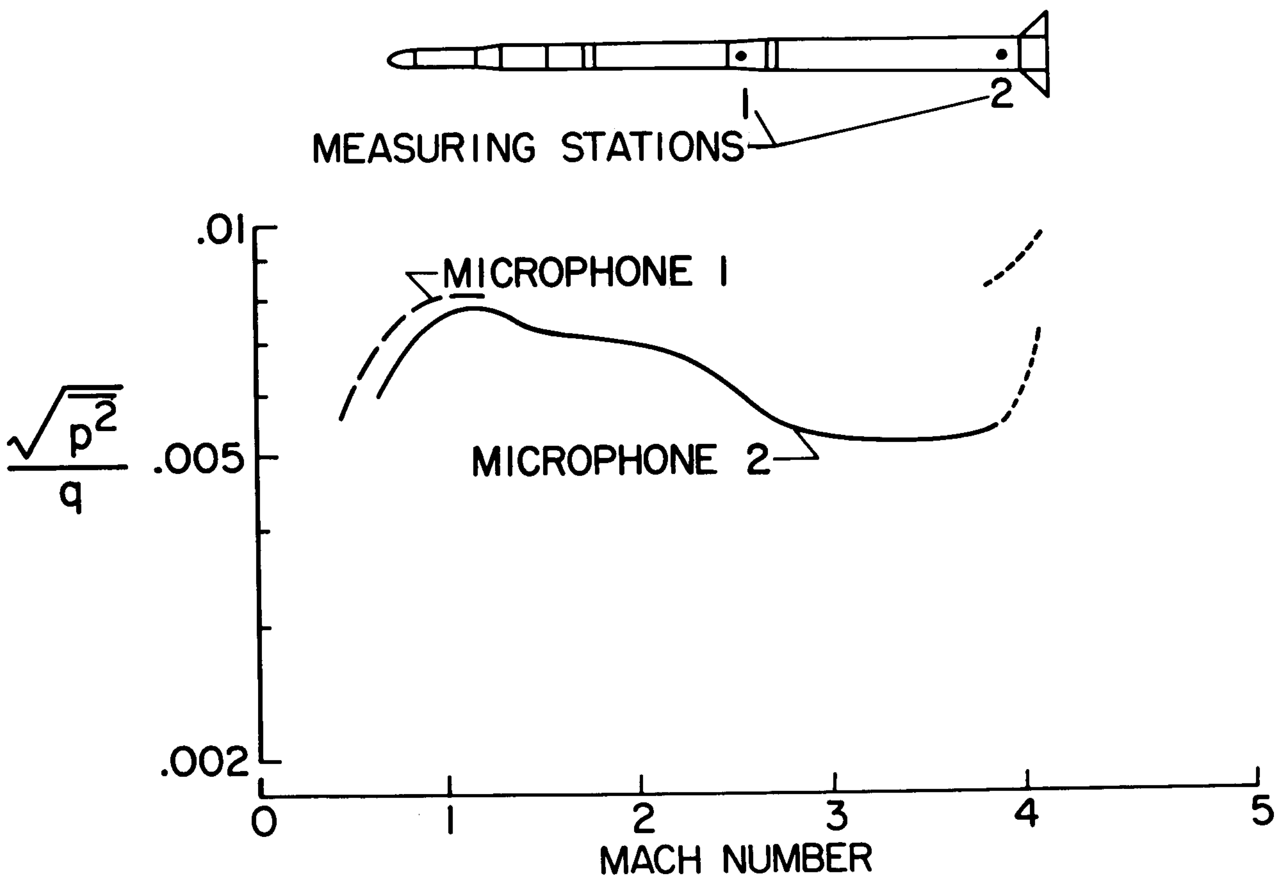

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Figure 6.- Surface pressures measured on Scout vehicle.

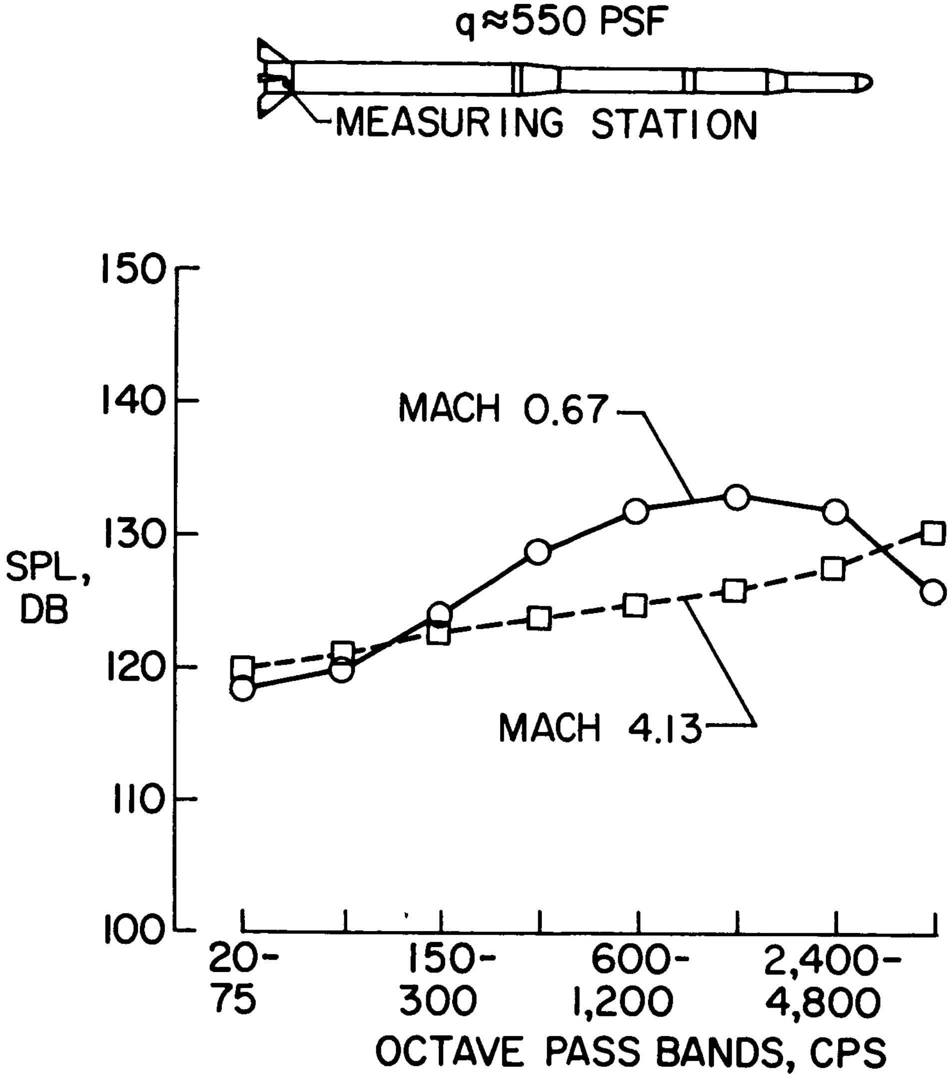

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Figure 7.- Sound spectra.

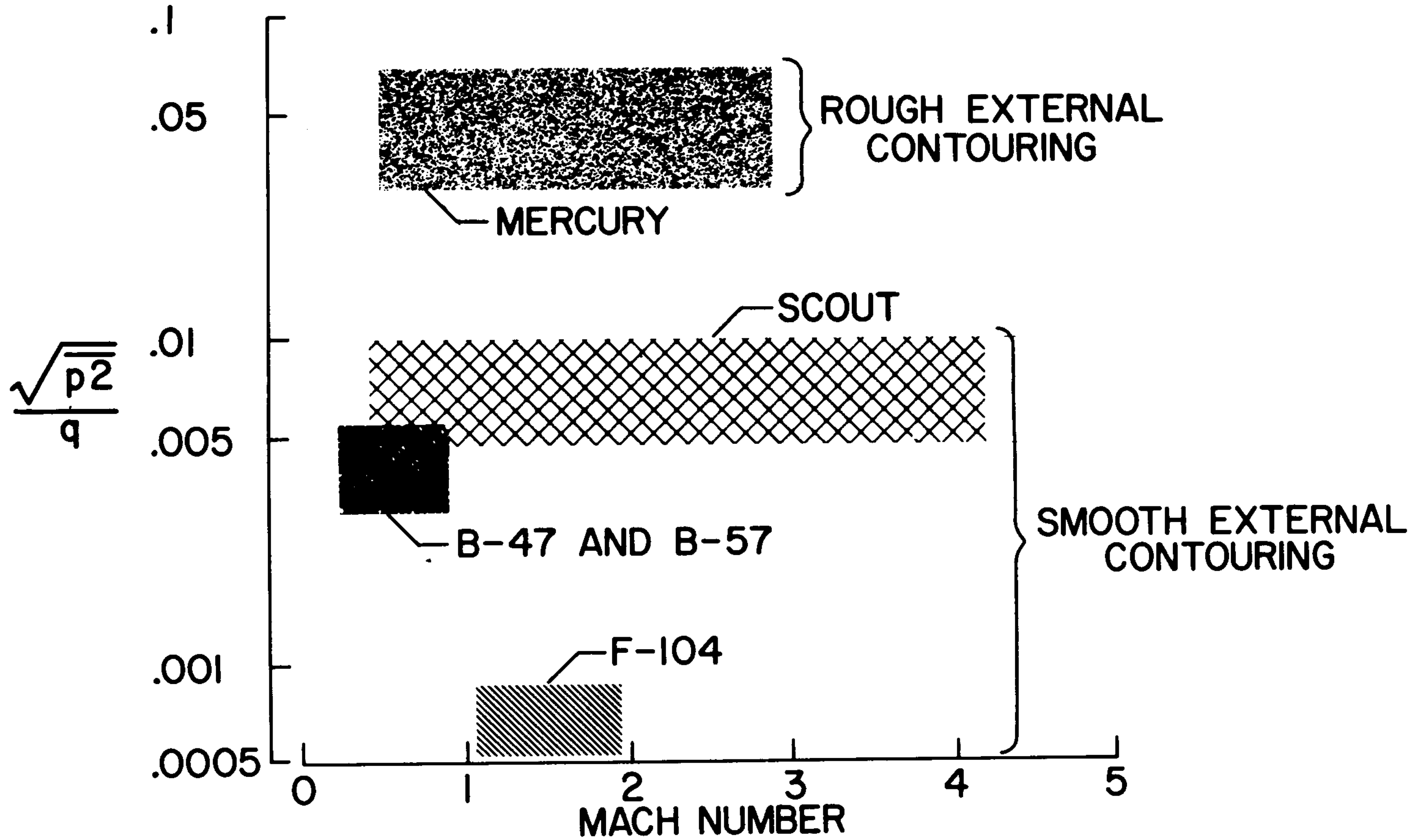

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Figure 8.- Boundary-layer noise pressure coefficient.

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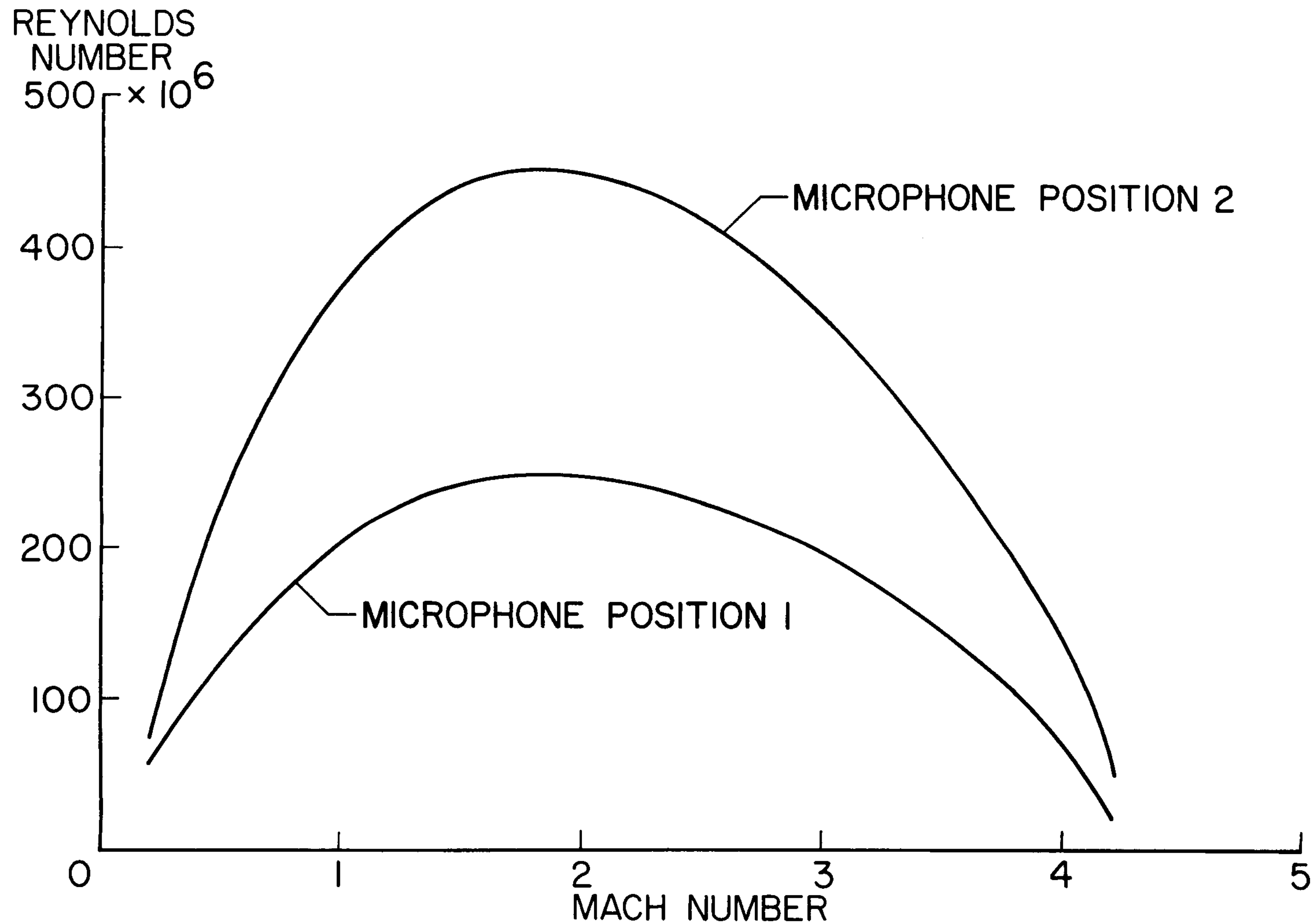

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